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ORIGIN AND EFFECTS OF *SPARTINA* WRACK IN A VIRGINIA SALT MARSH

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ABSTRACT Movements of mats of tidal wrack (dead *Spartina alterniflora*) and impacts of the wrack were followed in color infrared aerial photographs of a sloping foreshore salt marsh on Wallops Island, Virginia. Tidal wrack may be stranded in high marsh, where it decomposes, or it may be temporarily stranded at lower elevations. The wrack kills underlying *Spartina alterniflora* in low marsh and in the transition zone from low to high marsh. Wrack is the major cause of devegetated areas within the marsh, but these areas eventually revegetate, and do not evolve into pans. There are substantial short-term reductions in *S. alterniflora* marsh productivity. Other effects of wrack are discussed.

INTRODUCTION

Tidal wrack consists of dead plant material which forms mats that are rafted about by winds, tides, and currents (Warming 1904, Harshberger 1916, Nichols 1920, Conard 1935, Miller and Egler 1950, Kurz and Wagner 1957, Ranwell 1961, Teal 1962, Squires and Good 1974, McCaffrey 1976). In salt marshes of the eastern United States, wrack is mostly woody stems of tall growth form cordgrass, *Spartina alterniflora* (Teal 1962, Nadeau 1972, Squires and Good 1974), but in some areas eelgrass, *Zostera marina*, predominates (Kurz and Wagner 1957, Godfrey and Godfrey 1975).

Typically, thick floating mats are produced by winter wave- and ice-scouring of standing dead vegetation. These mats are often stranded in marshes by high tides. For wrack in marshes, the underlying soil surface replaces the estuary as the site of decomposition (Squires and Good 1974). Litterbag decomposition studies demonstrate that *Spartina* may take more than a year to decompose (Burkholder 1956, Burkholder and Bornside 1957, de la Cruz 1965). Microcommunities of amphipods, isopods, earwigs, and *Melampus* snails inhabit decomposing wrack (Wass and Wright 1969).

Where mats of tidal wrack remain in marshes for some time, the vegetation underneath often dies back from compaction and smothering (Warming 1904, Harshberger 1916, Nichols 1920, Conard 1935, Miller and Egler 1950, Kurz and Wagner 1957, Ranwell 1961, Stalter 1968, McCaffrey 1976). The diebacks leave devegetated patches of "secondary" bare soil (Chapman 1940), so-named because they were previously vegetated. Marsh pans are permanent, nonvegetated depressions in the soil surface that retain standing water at low tide (Yapp and Johns 1917). Several authors have suggested that patches of secondary bare soil devegetated by tidal wrack may become marsh pans (Warming 1904, Harshberger 1916, Nichols 1920, McCaffrey 1976).

So far there has been no systematic study of the origin or long-term effects of wrack in any salt marsh. This report deals with wrack in a young marsh on Wallops Island, Virginia. The impact of wrack was studied over two years.

METHODS

The salt marsh used in the Intensive Biometric Intertidal Survey (IBIS) project is part of Cow Gut Flat marsh, which is on northern Wallops Island, Virginia (Figure 1). It is a juvenile sloping foreshore marsh after Redfield (1972), dominated by tall (highest stalks 1.5 to 2 m) and medium (1 to 1.5 m) growth forms of *Spartina alterniflora.* Zonation resembles that of similar marshes in North Carolina (Davis and Gray 1966): monospecific stands of tall and medium growth forms of *S. alterniflora* in low marsh (below mean high water, MHW); medium growth form *S. alterniflora* intermixed with subdominates *Salicornia* spp., *Distichlis spicata,* and *Limonium* sp., in the transition zone from low to high marsh (from MHW to mean high water springs, MHWS); and *Spartina patens, D. spicata,* and some *S. alterniflora,* intermixed with saltbushes, *Iva frutescens* and *Baccharis halimifolia,* in high marsh (above MHWS). Mean tidal range along Cow Gut Flat is 0.8 m.

In April and May 1975, 203 hardwood stakes were set at 10 m by 10 m intervals within the marsh (Figure 2). Many parameters of the marked study site, including elevation, historical development, species distributions, population densities, productivity, and edaphic parameters, were studied during 1975 and 1976 (summary in Reidenbaugh 1978; see also Hoffman 1978; Crist, in preparation). Tidal data were calculated using estimates of the National Ocean Survey for Chincoteague Point, Virginia (Reidenbaugh 1978).

Color infrared (IR) aerial photos (Kodak film 2443) were taken of the study site at scales from 1:20,000 to 1:2,000 during seven National Aeronautics and Space Administration (NASA) overflights from 1974 to 1976. (Flight numbers are available in Reidenbaugh 1978.) Photos were enlarged to 1:1,333 on a reflecting projector and aligned by white reflectors on stakes, or (before stakes were set) aligned by conspicuous ground features. Boundaries of mapping units were traced on acetate and photoreduced (Figure 2). The species composition of mapping units was checked on the

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IBIS contribution 2.

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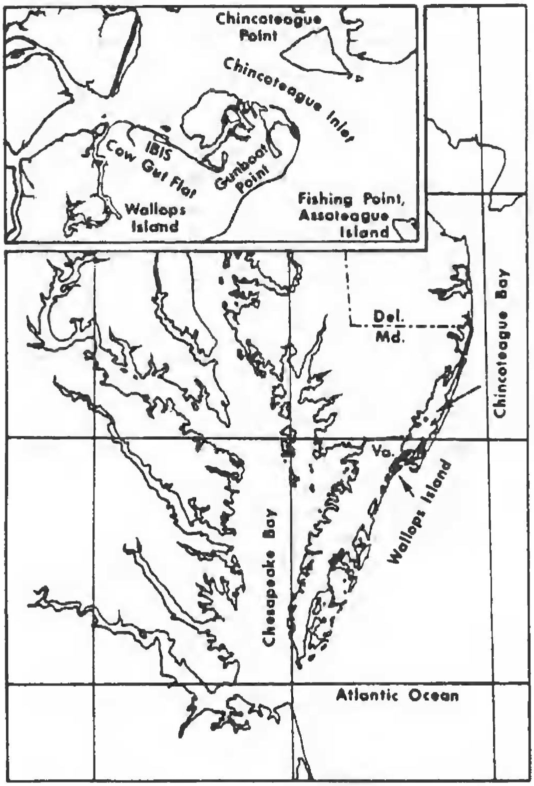

Figure 1. Locality map for salt marsh IBIS, Cow Gut Flat, Wallops Island, Virginia, 37°54′N, 75°26′W.

ground during three quadrat samplings of all stakes during 1975, and by standardized ground photos using black and white and natural color film. Eight mapping units were recognized for the purpose of this study:

1. An essentially monospecific stand of medium to high density *Spartina alterniflora*, with 190 to 550 overstory stalks per square meter, depending on mortality during the growing season (Reidenbaugh 1978). This zone consists of three areas recognizable in aerial IR photos:

    a. Tall *Spartina;* in low marsh areas with soft substrate. Highest frequently occurring stalks, 1 to 2 m. IR signature: textured pink to bright red in summer, textured dark green to blue-green in winter.

    b. Levee *Spartina;* in higher, quickly drained areas of firm, sandy substrate on a fossil sand bar and just below high marsh. Highest frequently occurring stalks, 0.5 to 1 m. IR signature: even green-red to red-tan in summer; even green to gray-green in winter.

    c. Middle marsh *Spartina;* in low, slowly drained areas with soft substrate. Highest frequently occurring stalks, 0.5 to 1.5 m. IR signature: mottled blue-pink to dark green-red in summer; mottled green to blue-green in winter.

2. Low density *S. alterniflora;* scattered in areas of levee and middle marsh *Spartina.* 70 to 170 stalks per square meter. Substrate firm to soft. Highest frequently occurring stalks, 0.5 to 1.5 m. IR signature: textured blue to blue-pink or blue-red in summer; textured blue in winter.

3. Saltbushes; areas dominated by *Iva frutescens* and *Baccharis halimifolia.* IR signature: individual bushes visible, pink to bright red in summer; green to gray-green in winter.

4. *Spartina* wrack. IR signature: textured blue-white to white or tan-white, all seasons.

5. *S. alterniflora* growing through *Spartina* wrack. IR signature: sparse, textured pink over *Spartina* wrack signature.

6. *Spartina* wrack mixed with saltbushes. IR signature: individual bushes visible; pink to bright red in summer, green to gray-green in winter; white wrack visible around bushes.

7. Bare marsh soil. Little or no rooted vegetation. IR signature: even light blue to dark blue.

8. A pan similar to bare marsh soil (7), but darker blue-black in IR photos, or with sun glint at low tides. Recognizable by its presence in imagery for over 10 years.

More specific details on the composition of the mapping units used herein are available in Reidenbaugh (1978).

All eight units are mapped in Figure 2. Although similar maps were prepared for all the relevant imagery (Reidenbaugh 1978), it was convenient here to further lump the vegetation categories as follows (Figure 3): categories 1 and 3 were lumped as "salt marsh"; low density *S. alterniflora* (category 2), bare soil (category 7), and pans (category 8) were not changed. Only a few of the maps prepared are illustrated here.

Additional observations of wrack were made *in situ* in 1978.

RESULTS AND DISCUSSION

Mats of tidal wrack were first observed in early June 1974 (Figure 2). New mats were deposited during spring 1975, 1976, and 1978 (no data for 1977) (Figures 4 and 5). New wrack did not appear during any other time of the year. Apparently, wrack was formed by wave- and ice-scouring of the previous season's dead vegetation. Wrack entered the marsh well after scouring each year, presumably because it was ice bound and because tide levels in early spring are low (Marmer 1951). At Salt Marsh IBIS, average high tide levels may be 0.3 m lower in winter than in late summer (Reidenbaugh 1978). The wrack was composed almost entirely of detached leaves and leafless stalks of tall growth form *S. alterniflora* (Figure 5). The tall growth form can be recognized by the longitudinal distance between whorls of leaf scars (see Reidenbaugh 1978). Tall growth form *S. alterniflora* grows along the lowest, most seaward edge of the marsh, and is therefore much more susceptible to winter

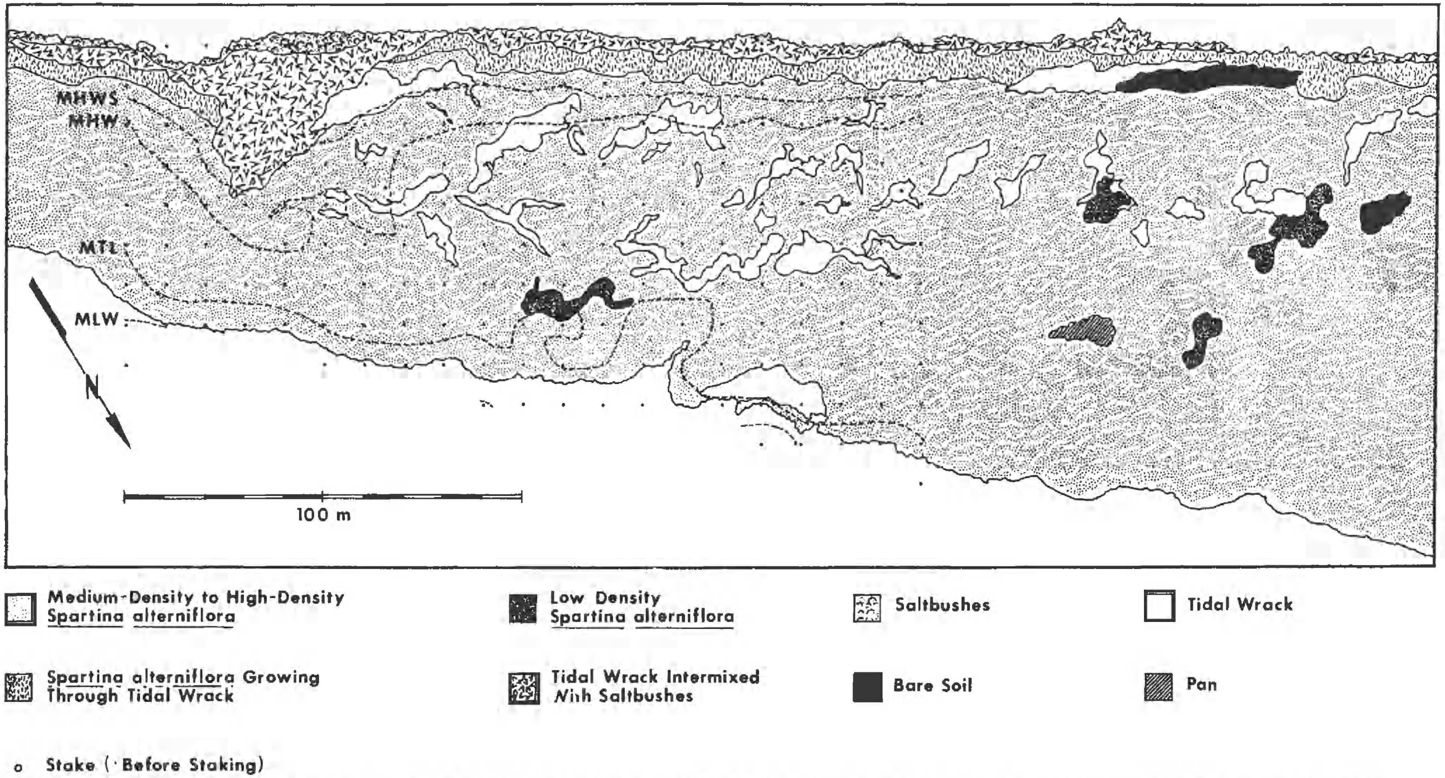

Figure 2. Map of cover types in the study area, June 4, 1974. Upland at top, Chincoteague Bay below. Dots represent locations of stakes set in place the following year; compare Figures 3 and 7. Dashed lines indicate tidal datum planes. Base map: NASA Mission W735, July 19, 1976; this map: NASA Mission W271, June 4, 1974.

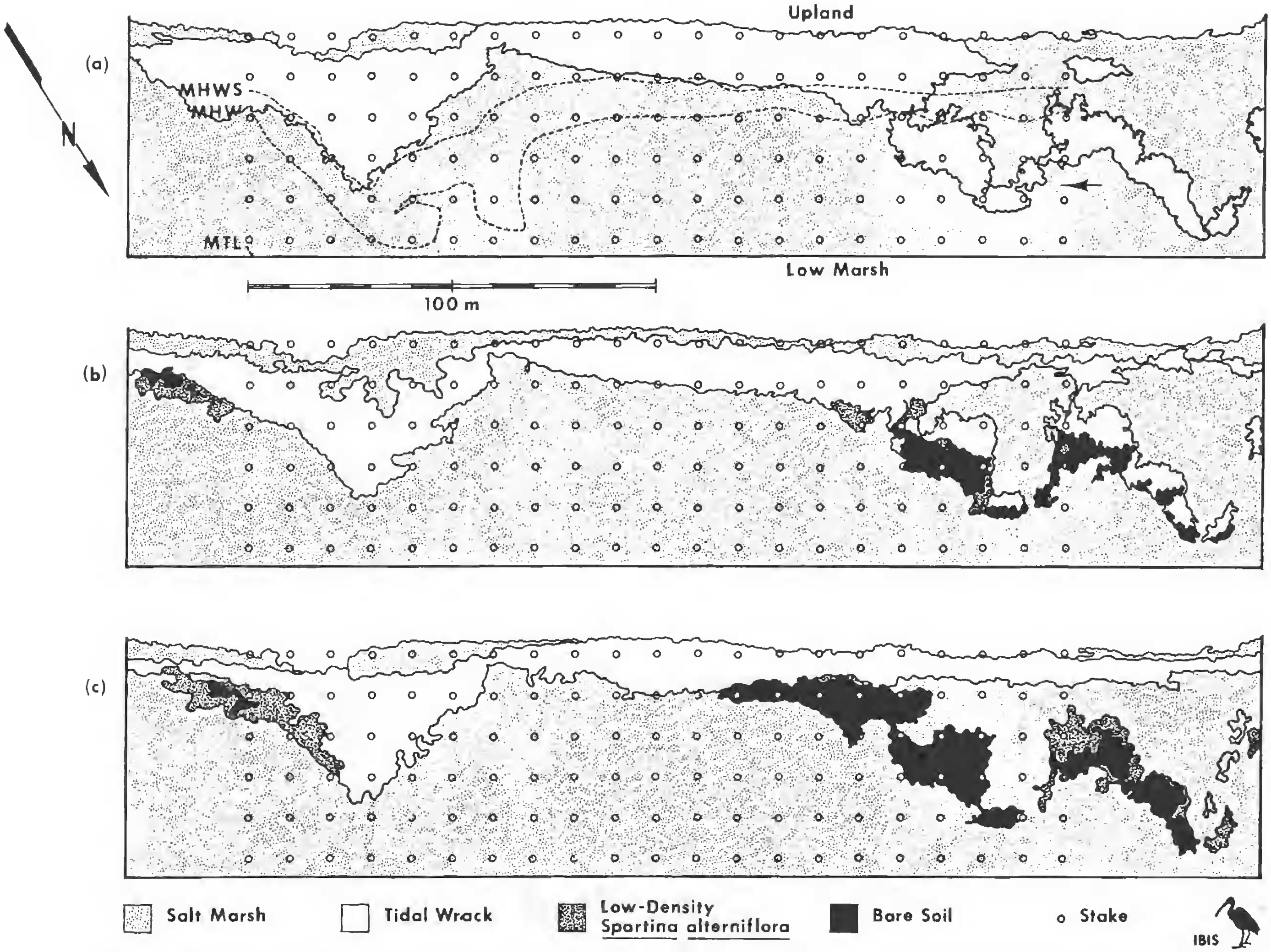

Figure 3. A single year's devegatation by tidal wrack in the upper part of salt marsh IBIS. Compare Figure 2. (a) NASA Mission W324, May 28, 1975; (b) NASA Mission W343, September 3, 1975; (c) NASA Mission W353, November 26, 1975. About 6 months between (a) and (c).

Figure 4. Medium growth form of *S. alterniflora* in salt marsh IBIS, May 20, 1975. The location and direction from which the photo was taken is indicated by the arrow at right in Figure 3(a).

Figure 5. Medium growth form of *S. alterniflora* in salt marsh IBIS, July 23, 1975—two months later than Figure 4. Mats of wrack cover the grass at left.

scouring than are the shorter growth forms. Tides are lowest in the winter when most scouring occurs, so lower elevations are more heavily and more frequently subjected to scouring by waves and ice.

Conspicuous mats of wrack were not seen until just after spring ice melts, during time of increasing tide heights. Most of the wrack seen in the IBIS marsh probably originated nearby; little wrack was ever seen floating offshore, despite near-daily observations during the spring of 1975 to 1977. It seems likely, therefore, that little long distance transport takes place.

Compared to adjacent areas, the IBIS study site received relatively large amounts of wrack. The study site is more directly exposed to waves and drifting ice from Chincoteague Bay than adjacent areas, which are protected by geographical features such as marsh islands or sand. No evidence was found to suggest that the stakes affected accumulation of wrack—there was about as much before staking as after (compare Figures 2 and 3).

Mats of wrack were rafted upward in the marsh by increasingly high tides; as the tides went out, mats were left behind. Mats stranded in low marsh, or in the transition zone from low to high marsh, were soon moved higher. Once mats made it to high marsh, they remained in place and gradually decomposed. Significant downward movement occurred only once (April 1976), but even then, only relatively small amounts were involved.

Upward movements of mats probably result from three effects. (1) Tide heights gradually increase from spring to fall. (2) Seasonal storm tides caused by northeasterly or southeasterly winds drive water through Chincoteague Inlet, increasing the water level. Storm winds slow ebb tides and blow wrack into the marsh. (3) Winds bend *Spartina* stalks toward the upland. This permits wrack to drift over them, but slows it when the wrack tends to drift back.

New wrack can be distinguished from old wrack, both in the field and in IR photos.

"New" wrack, wrack settled during the same growing season, forms thick mats often over 20 cm deep. It is composed of densely interwoven, long, hard stems and some dead leaves. New wrack generally is at lower elevations than old wrack, or often overlays it. In color IR, new wrack is very light, nearly white. When wet it is tinged with tan or blue. The texture is coarse, and the underlying substrate is completely obscured.

"Old" wrack, from the previous growing season, forms thinner mats, usually less than 20 cm deep. Mats are composed of short stem fragments, partly decomposed, and various amounts of finer detritus, increasing with age. Old wrack was seen only at higher elevations, often piled in the saltbush zone. Old wrack often contains more water than new wrack. In IR photos, old wrack has a smoother texture than new wrack, and is slightly darker. *S. alterniflora* may grow through old wrack, appearing pink and heavily textured. Where wrack is partly obscured by saltbushes, old and new wrack are hard to distinguish by IR photos, and only field observations will do.

Spartina wrack may kill large amounts of underlying vegetation under certain conditions (Figures 4, 5, 6 and 7). Mats stranded in low marsh for more than a few weeks in the spring caused complete devegetation. Wrack stranded later in the growing season caused only partial devegetation in low marsh. Presumably, taller *Spartina* plants survive better than sprouts. At higher elevations, in the transition zone from low to high marsh, mats usually caused only partial devegetation, even in spring. At high elevations, where wrack is stranded most of the year, eventually *S. alterniflora* will emerge through the wrack, but partial or complete diebacks sometimes occurred. Narrow patches of bare soil and low density *Spartina* resulted (Figures 6 and 7). This may account for the "barren zone" described by Guss (1972) from aerial photos in which wrack also was seen.

The movements and effects of wrack in the IBIS marsh are summarized in Figure 8.

Figure 6. Medium growth form of *S. alterniflora* in salt marsh IBIS, January 5, 1976–five months later than Figure 5. The wrack has killed back underlying vegetation, leaving secondary bare soil.

Amounts of marsh devegetation by tidal wrack varied greatly from year to year. In low marsh, and in the transition zone from low to high marsh, there were fourteen local diebacks in 1974, and eight in 1975. These devegetated areas totaled about 0.1 ha of marsh each year. In 1976, there were no diebacks below high marsh; extraordinarily high tides rafted wrack into high marsh in early spring before the *S. alterniflora* growing season, precluding diebacks at lower elevations.

Vegetation diebacks beneath tidal wrack did not form pans in the marsh, although significant short-term erosion occurred in devegetated areas. Patches of secondary bare soil eroded at an average rate of 5 mm yr^{-1}, over 3 years; patches of low density *S. alterniflora* eroded at 4 mm yr^{-1} (Varricchio et al., in preparation). During the same time, surrounding marsh areas of medium to high density, medium growth form *S. alterniflora* accreted at 1 mm yr^{-1} (Varricchio et al., in preparation). In some cases, patches of secondary bare soil persisted more than 2 years, but all eventually revegetated. In this juvenile marsh, organic content of sediments may be too low (2 to 4% by weight), and sand content too high (84 to 91% by weight) (Reidenbaugh 1978), to allow secondary pan formation by below ground organic decomposition and sediment compaction. The only pan in the Cow Gut Flat marsh formed as a primary pan when it was isolated in a relatively low area behind a sand bar by marsh colonization at both ends of the bar. In marshes where organic content is higher, decomposition combined with erosion may possibly lead to pan formation.

Vegetation diebacks were the major cause of low density *S. alterniflora* areas, and the sole cause of secondary bare soil areas in the marsh during this study. This temporary devegetation substantially reduced *S. alterniflora* productivity of the marsh. In medium to high density areas of medium growth form *S. alterniflora*, adjacent to devegetated areas, the net aerial productivity ranged from 580 to 1,020 g dry weight m^{-2} yr^{-1}. In bare soil and low density *S. alterniflora* areas, productivity was reduced from 0 to 400 gm^{-2} y^{-1} (Reidenbaugh 1978). In 1976, 11% of the total *S. alterniflora* marsh area in the study site (15% of the medium growth form area), had been wholly or partly devegetated by tidal wrack; total *S. alterniflora* net area productivity of the site was reduced 8% (medium growth form *S. alterniflora* productivity was reduced 15%) compared to nonaffected marsh (calculated from Reidenbaugh 1978).

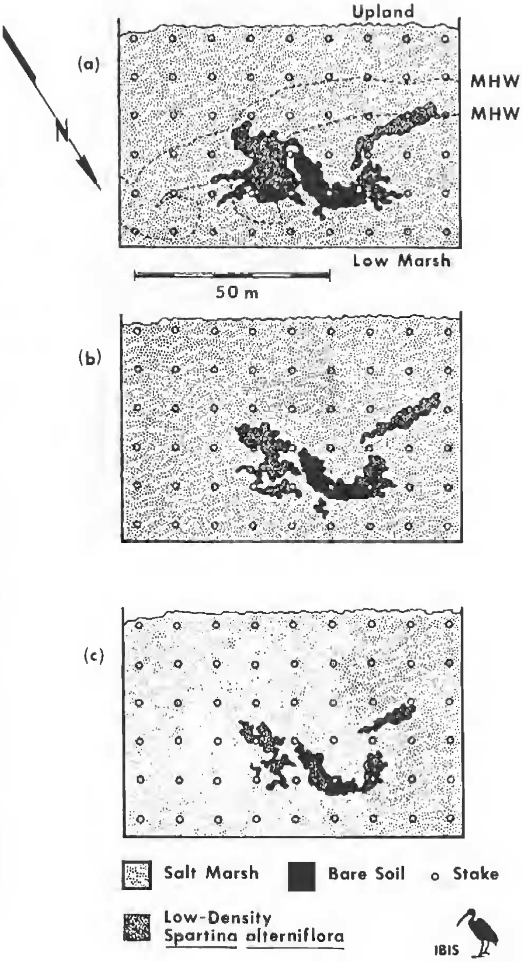

Figure 7. Revegetation of areas of marsh devegetated by wrack in 1974. (a) NASA Mission W324, May 28, 1975; (b) NASA Mission W353, November 26 1975; (c) NASA Mission W383, August 11, 1976. About 15 months between (a) and (c).

Wrack may be a major pathway of bulk detritus flux in some marshes. Much of the plant biomass produced in low marsh is transported upward in the marsh as wrack, and eventually decomposes in high marsh. Some of this biomass

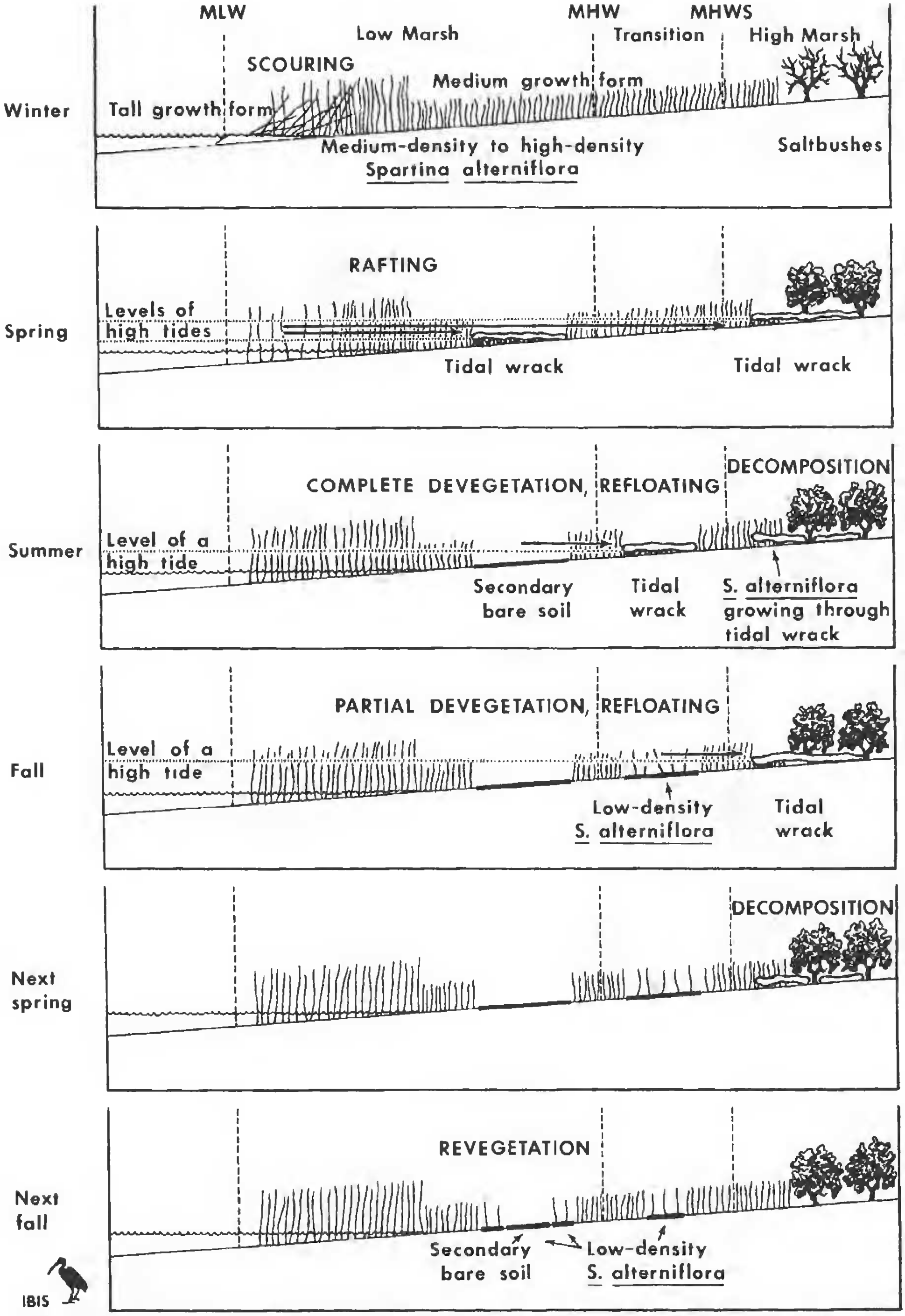

Figure 8. Diagram of the origin and effects of tidal wrack in salt marsh IBIS. Suggestions by M. A. Champ led to this artwork.

is incorporated into high marsh soils as organic material. High marsh at Cow Gut Flat was formerly an uncolonized beach ridge. Though organic content of the high marsh soils is only 3%, it is greater than in most lower marsh zones in this juvenile marsh (Reidenbaugh 1978). Most of the biomass is leached from wrack as finer detritus and probably enters the water column during tidal flooding. In high marsh, wrack detritus may contribute to sediment accretion. At Cow Gut Flat, short-term high marsh accretion is 2 mm yr^{-1} (Varricchio et al., in preparation). In low marsh and in the transition zone from low to high marsh, devegetation caused by wrack results in sediment erosion, at 4 to 5 mm yr^{-1} in this marsh (Varricchio et al., in preparation). Here, the organic content of sediments is very low compared to other marshes; erosion probably occurs from increased tidal and wind scouring in devegetated areas, and from decreased interference with the water column to cause settling of suspended particles.

SUMMARY AND CONCLUSIONS

Mats of tidal wrack and areas devegetated by wrack are transitory features in salt marshes. They may be successfully monitored in sequential color IR aerial photos.

New mats of tidal wrack are formed by winter scouring of standing dead stalks of tall growth form *S. alterniflora* in lowest low marsh, and are rafted upward into the sloping foreshore salt marsh each spring. The mats settle over emergent vegetation from low to high marsh, depending on tide height. Mats stranded in high marsh decompose in place and living vegetation emerges through the wrack. Mats stranded in low marsh or in the transition zone from low to high marsh are refloated to high marsh by successively higher tides during summer or fall.

If mats cover areas of low marsh or the transition zone from low to high marsh during the growing season, underlying medium growth form *S. alterniflora* wholly or partly dies back, forming patches of secondary bare soil or low density *S. alterniflora*. Diebacks beneath tidal wrack are the major cause of devegetated areas within the Cow Gut Flat marsh. Severity of diebacks depends on marsh elevation, and time of year during the growing season of vegetation covered by wrack, with most serious diebacks occurring in low marsh, and in spring. Amounts of marsh devegetated varied greatly between years, depending on highest tide levels during early spring.

Secondary bare soil devegetated by wrack may persist 2 years or more. However, in this marsh, all devegetated areas eventually revegetated, and did not evolve into secondary pans. Sediment erosion occurred in devegetated areas, but it was suggested that organic content may be too low, and sand content may be too high, in the juvenile marsh sediment to allow pan formation by below-ground decomposition and compaction. Pans have formed only for geological reasons in this marsh.

Temporary devegetation caused by tidal wrack substantially reduced *S. alterniflora* productivity in the Cow Gut Flat marsh. As much as 11% of the *S. alterniflora* marsh area may be devegetated, and total *S. alterniflora* net aerial productivity may be reduced as much as 8%. Scouring and rafting of tidal wrack are enhanced by direct wave exposure of the marsh; because the Cow Gut Flat study site is directly exposed to waves from Chincoteague Inlet, measured impacts of tidal wrack are probably relatively very high.

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